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RADAR BULLETIN NO. 1

(RADON)

THE TACTICAL USE OF RADAR

~~CONFIDENTIAL~~

FF1/S67
Serial 0859

UNITED STATES FLEET
HEADQUARTERS OF THE COMMANDER IN
NAVY DEPARTMENT, WASHINGTON, D

March 9, 19

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the application of information received by means of

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RUSSELL WILLSON
Chief of Staff

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REFERENCE PUBLICATIONS

The following is a list of available technical and publications upon which this bulletin is based.

1. "Radar Technical Bulletins." (Eng.129) (Confident
   No. 1. "General Information on Radar Equipment."
   No. 2. "Estimating the Altitude of Aircraft by Ra
   Observation."
   No. 3. "Amplidyne Control of Radar Antennas."
   These bulletins are published by the Bureau of Sh

2. Ordnance Pamphlets (Confidential).
   ORD 656. "Operation of Fire Control Radar Type FA
   ORD 657. "Operation of Fire Control Radar Types F
   These pamphlets are published by the Bureau of Or

3. "Tentative Radar Doctrine." (Revised October 6, 1
   Commander in Chief, U.S. Pacific Fleet Operation
   No. 31-41.

4. "Tentative Doctrine for Fighter Direction from Ai
   Carriers."
   This is enclosure A to CNO confidential letter Op
   (QB/IC) (SC) S67/S71 serial 0208222 of August 6
   Subject: Fighter Protection of a Naval Force.

5. "Radar in Pacific Fleet Landing Exercise Number 0
   Commander Scouting Force confidential letter to C
   S67(1)/(95) serial 0814 of October 13, 1941.

6. "Radar Installation Plan."
   Bureau of Ships C-S67/36(485) C-EN28/A2-11 of Jul
   1941 (with changes).

7. "Instructions for Fighter Direction." CSP 1291.
   "Vocabulary for Fighter Direction." CSP 1292.

8. "Essentials of Various Types of Radar Equipment."
   CNO confidential letter Op-22 (QB/IC) (SC) S67/S7
   0212622 of October 8, 1941.

THE TACTICAL USE OF RADAR

I. INTRODUCTION

The object of this bulletin is to enable the officer pe
ships and operating forces to make the most efficient us
equipment that is installed in their ships, by providing
available information on operating experience in the use of R
by both the British and United States Fleets. It is intende
pamphlet serve as a guide to officers other than those hav
cognizance of the technical or operational aspects of Radar.
to be considered as a final Radar doctrine.

Radar equipment is constantly undergoing improvement in
hard and fast rules for its tactical use cannot be laid down
of this pamphlet may be expected as dictated by experience o
ating forces afloat and new developments in equipment.

II. THEORY AND OPERATION OF RADAR

A. THEORY

In order that all officers concerned may have a general k
the theory of Radar operation, the following brief notes are

Radar operation consists of sending out a series of impuls
tromagnetic energy from a high-power, ultra-high-frequency r
mitter. These impulses are directed into a beam by a d
antenna, reflected by objects which they strike, received b
antenna, and fed into a radio receiver. Only a small port
transmitted energy is reflected back to the antenna. Th
between the transmission of successive impulses is suffici
for each one to go out and return from a target at the max
of the set. Thus there is no interference between returni
The transmitter and receiver are so operated that the tim
hundred millionths of a second) between the transmission and
of each impulse can be measured and converted into a rang
indicated by the position of a "pip" on the screen of a catho
In order to provide a steady range indication, a large num
pulses are transmitted each second.

Directivity (bearing) is obtained by a rotating directional ant which, when used with a gyro compass repeater, provides true beari Radar bearings may be fed into the target designation system and i cated in the Pilot house, air defense forward, and Radar Pl

Radar elevation angle is obtained directly from a dial sho antenna elevation angles on the fire control sets. The longer r detection sets have no feature which permits satisfactory alti estimates of aircraft targets, which is of great importance in fig direction. A rough estimate of altitude can, however, be made by of carefully prepared calibration charts using null points. R Technical Bulletin No. 2 fully explains the preparation of these ch and their use.

B. RELIABILITY OF RADAR RANGES AND BEARINGS

1. RANGE

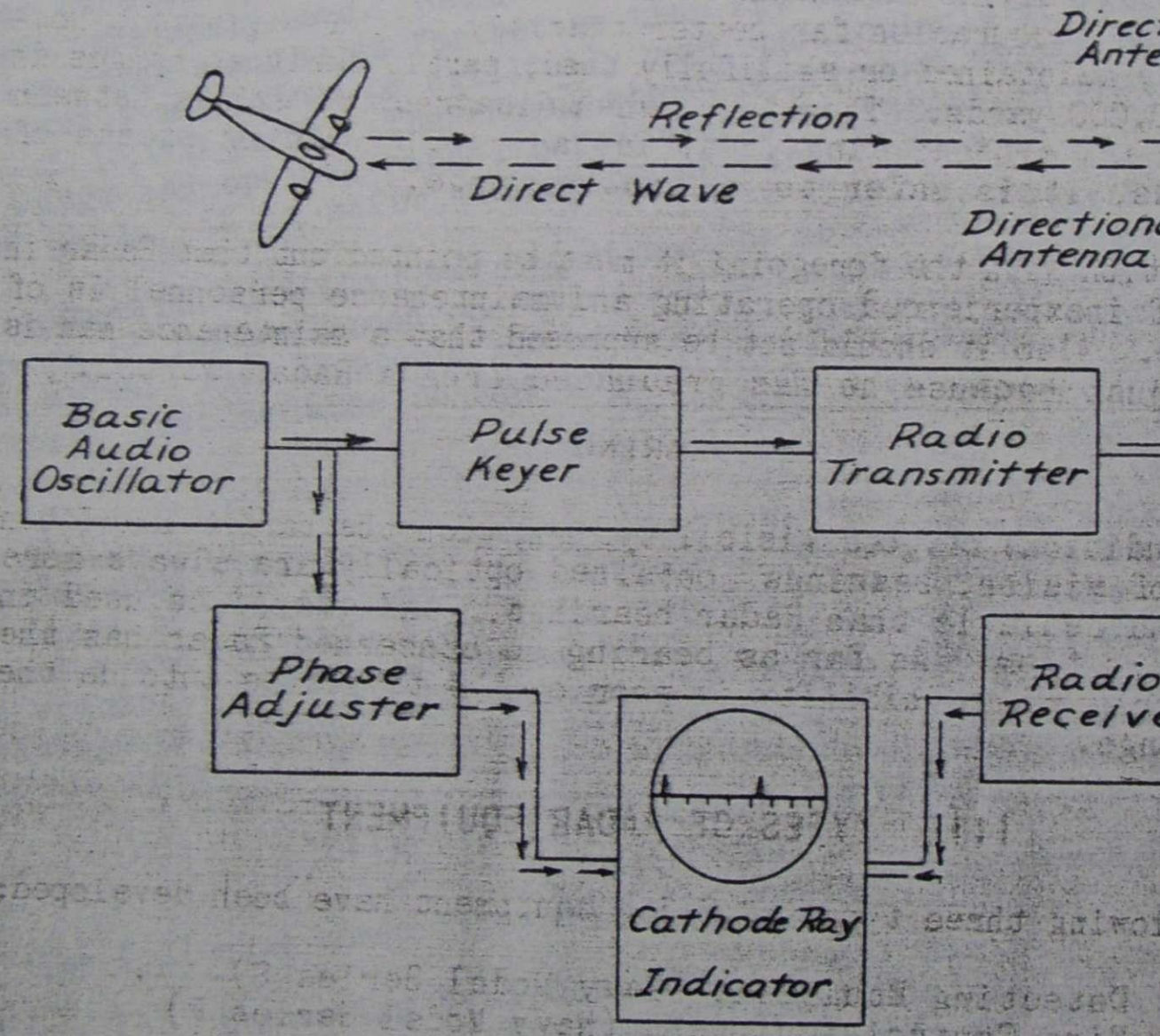
Ranges obtained with properly functioning Radar equipment are erally more reliable than those obtained with ordinary coincidenc even stereoscopic rangefinders. This is particularly true in the of fire control Radar equipment. For example in the *HOOD-BISM* incident, the *HOOD'S* optical rangefinder identified the opening r of the *BISMARCK* as 23,000 yards, whereas the corresponding Radar r was given as 27,000 yards. The range given by the optical rangefi was used and the opening salvo fell short by approximately 4,000 ya

Several conclusive arguments may be advanced in support of reliability of Radar range over optical range:

(a) Errors which may exist in Radar ranges are essentially cons throughout each range scale and are relatively small.

(b) At the outset of an engagement it is quite possible that human element will cause errors in ranges obtained optically, especi in extreme ranges. On the other hand, Radar ranges appear on the hode ray tube unaffected by the human element. It can be determ immediately whether a Radar range is available for use, because ranges either appear on the screen or they do not.

(c) Signal strength does not materially affect the accurac Radar range, since range appears on the screen of the cathode ray as a linear dimension with quantitive significance, viewed at rig


Direc
Ante
Reflection
Direct Wave
Direction
Antenna
Basic
Audio
Oscillator
Pulse
Keyer
Radio
Transmitter
Phase
Adjuster
Radio
Receiv
Cathode Ray
Indicator

It is, therefore, of the utmost importance that all ship's Radars maintained in perfect operating condition at all times.

Too much emphasis cannot be placed on the need for periodically cal brating all Radars. There are several types of characteristic erro which exist in all types of Radar equipment, and only by frequent, acc rate calibration can the correct zero setting be determined for each at all times.

Radar carelessly used will give ranges as accurately as optic equipment carelessly used. Radar expertly kept up and skillfully us will give range accuracies far better than any optical equipment ho ever expertly maintained or skillfully used, particularly at ranges excess of 10,000 yards. Therefore, when disagreement exists betwe Radar range and optical range, particularly at ranges in excess 10,000 yards, it is safer to use Radar range.

In connection with the foregoing it must be pointed out that Radar the hands of inexperienced operating and maintenance personnel is little value. Also it should not be supposed that a maintenance man an expert just because he has graduated from a Radar school.

2. BEARING

Under conditions of good visibility, and when the target is with the range of vision, bearings obtained optically are always mo accurate and reliable than Radar bearings, and should be used preference to them. As far as bearing is concerned Radar has t advantage only when visibility is poor or the target is outside t visible range.

III. TYPES OF RADAR EQUIPMENT

The following three types of Radar equipment have been develope

(1) Detecting Equipment (Navy Model Series S)
(2) Fire Control Equipment (Navy Model Series F)
(3) Recognition Equipment (Navy Model Series B)

Experimental equipment of these three classes are given the usu CX or X model assignments. Radar apparatus designed for use in ai craft is assigned in the Navy Model Series "A" succeeded by "S," "F

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CHARACTERISTICS OF RADAR EQUIPMENT

MODEL	PURPOSE	RELIABLE RANGE ON SURFACE SHIPS (MILES)	RELIABLE RANGE ON LARGE PLANES (MILES)	RANGE ACCURACY (YARDS)	BE ACC (STAT
CXAM (6 sets) CXAM-1 (14 sets)	MEDIUM RANGE SHIP AND AIRCRAFT DETECTOR INSTALLED ON SOME BB, CA, CV AND AV.	5-10	35	±200	
SC SC-1 (improved)	MEDIUM RANGE AIRCRAFT DETECTION RADAR FOR BB, CA, CB, CL, CV, DD AND OTHER VESSELS	4-10	10-25	±100-200	±
SC with CXAM-1 ANTENNA	ONE INSTALLATION IN U.S.S. WASP	PERFORMANCE SHOULD BE SUPERIOR TO CXAM-1 AND SC, BUT NO REPORTS OF TESTS ARE AVAILABLE.			
SD	AIRCRAFT WARNING DEVICE FOR SUBMARINES. ANTENNA IS NON-DIRECTIONAL	5	12	±500	
SH	SURFACE CRAFT DETECTOR FOR SHIPS	7-14	-	±25	
SJ	SHIP DETECTOR FOR SUBMARINES WITH TORPEDO FC APPLICATION	3-6	-	±25	±
FA	GENERAL PURPOSE DETECTING AND FIRE CONTROL RADAR. 10 MANUFACTURED. NOW BEING REPLACED BY MODEL FC	3-5	9-15	±50	±
FC	MAIN AND SECONDARY BATTERY DIRECTOR RADAR	5-10		±25	±
FD	ANTI AIRCRAFT AND DOUBLE PURPOSE BATTERY DIRECTOR RADAR	5-10	5-15	±10-15	±
FH (Mk.8)	MAIN AND SECONDARY BATTERY DIRECTOR RADAR TO REPLACE MODEL FC	5-10		±25	
ABA BI	IDENTIFICATION EQUIPMENT USED WITH RADAR				
IFF Mk.II	BRITISH SET INSTALLED IN A NUMBER OF VPB	EMPLOYED PRINCIPALLY TO IDENTIFY OUR PLANES TO BRITISH SHIPS AND GROUND STATIONS			
IFF Mk.II N (ABD)	BRITISH SET ON ORDER IN LARGE QUANTITIES	THIS EQUIPMENT CAN BE USED WITH CERTAIN SC AND CXAM-1 SETS AS WELL AS BRITISH DETECTION EQUIPMENT			

The function of detecting Radar equipment is to act as a gene searching device to obtain indications of the presence, range and be ing of unknown ships or aircraft. Primarily this function invol detection of such craft at ranges greatly in excess of that at wh visual observation or gunfire would be effective.

Since maximum range is dependent on height of antenna, ship cont Radar antennas are always installed at the highest possible points the ship.

Ship control equipment and fire control equipment in the same s have fundamentally different characteristics which allow them to p form their *primary* functions best, generally at the expense of other functions. Thus in order for detecting equipment to obt echoes from aircraft at the long range mentioned above, some sac fice is made of effective range at low altitudes, accuracy of ra and bearing, and degree of resolution between targets. For th reasons a ship control Radar set is a good aircraft detector bu poor surface craft detector. Similarly a main battery fire cont Radar set is a good ship detector but a poor aircraft detect

B. FIRE CONTROL EQUIPMENT

This type of Radar equipment includes Models FA, FC, FD, and In addition the Model SJ detecting set for submarines embodies a t pedo fire control application.

Radar equipment which is connected with fire control apparatus designed to obtain ranges and bearings accurately, and, in the c of anti-aircraft director equipment, also elevation angle. T equipment supplements optical rangefinders and fire control equ ment. The effective range, because of the mounting of antennas directors or at other points not usually as high above the wate line as those used for detecting equipment, may be less than that the latter type of Radar. The range of anti-aircraft director Rad should be much greater than that of similar optical devices, and equipment will function accurately under conditions precluding t operation of optical equipment.

As mentioned above, main battery fire control Radar equipment better for surface craft detection than for aircraft detection. other important function is searching for surface craft during pe iods of reduced visibility, or for shadowing aircraft flying at

C. IDENTIFICATION EQUIPMENT FOR USE WITH RADAR

Radar identification equipments include Models BI and ABA (Air
In addition there are two types of British IFF (identification,
or foe) equipment being installed in some of our planes. These
IFF Mk. II (SCR 535) and IFF Mk. II N. (Model ABD).

Recognition devices are designated to furnish a means of iden
unknown targets, either surface ships or aircraft, when they ha
detected by the Radar set. The operation of the identification
ment, usually controlled automatically by the Radar, transmits a
which is observed by the Radar operator, thereby identifying th
as friendly. The absence of such a signal, however, *does not* i
the craft as an enemy, since, if it is a friendly ship it may
IFF equipment or if it does have the equipment it may not be fu
ing properly. Obviously to be totally effective, identification
ment must be universally installed in all friendly ships and ai
but at the present time this condition is far from having been at

D. AIRCRAFT RADAR EQUIPMENT

There are two classes of airborne Radar equipment:

(1) ASV Detecting set for use against surface vess
(2) AI Detecting set for use against other aircraft,
cularly for installation in night fighters.

IV. CAPABILITIES OF RADAR EQUIPMENT

More complete data on Radar sets is to be found in the ref
publications, but for the sake of ready reference a table of
characteristics is given on page 5. It should be noted tha
figures in this table are average only. Individual sets of a
Model classification may give results which are in excess or fal
of those listed for that particular model. Therefore careful r
of the performance of each set should be kept at all times in or
determine its capabilities under various conditions. Radar can b
to the best advantage only when the operating personnel know what
particular set will and will not do.

A. CAPABILITIES OF DETECTING RADARS

2. Warning of the presence of enemy surface craft that are bey the visible range, so that the correct disposition of the fleet may made to meet an attack, or preparation made to attack the enemy by s prise. It must be remembered that Detecting Radar equipment is n effective for No. 1 than for No. 2.

3. Indication to be given to other ships in own force of the ection from which either an air or surface attack will devel

4. Fighters to be flown off in time if an air attack is immi and a carrier is in company.

5. A fighter escort to be called for in sufficient time if carrier is in company.

6. Constant observation of the movements of enemy aircraft, detected, and the direction of own fighter planes to a position su able for interception.

7. Provision of security against night attack, attacks dur conditions of poor visibility, or from behind a smoke screen

8. Scouting.

9. Screening.

10. Obtaining bearings (but not ranges) of other Radar equip ships up to considerable distances; greater than the maximum at wh echoes can be received.

11. Obtaining meteorological data from balloons.

12. Obtaining range and bearing of prominent landmarks and la buoys, thus serving as a navigational aid at night and during low v ibility. When ranging on the shore line echoes from higher land f ther inland must not be mistaken for the shore itself.

13. Ranging on distant land up to 200,000 yards.

14. By keying the CXAM transmitter it has been found possible communicate between ships equipped with this type equipment.

B. CAPABILITIES OF FIRE CONTROL RADARS

using fire control Radar apparatus it is at present advisabl obtain bearings optically whenever possible, and supply only ra from the Radar in order to obtain the most accurate solution of fire control problem. Using this method, success has been obtain arriving quickly at a satisfactory solution in the rangekeeper. S range inputs allow full use of rate control methods to produce in one-half the time required with optical ranging, a rangekeeper sol that will hold on the target without variation.

2. The detection of surface craft during periods of reduced ibility.

3. The detection of low flying enemy shadowing aircraft

4. Supplying useful tactical information such as the positi other ships in own force, and greatly facilitating station keepi night when all ships must be darkened.

5. Acts as a distant limited warning device in the absenc ship control Radar equipment. It should be noted here that if a control set becomes inoperative, the ship control set may be used fire control purposes, but it will supply less accurate dat

6. Supplying data for the direction of starshell or searchl illumination.

7. Spotting by ranging on shell splashes. At short ranges possible to follow the projectile with the radar. This will giv indication on the screen as of a mouse running along under a sh Echoes from "over" splashes may not show up on the screen becaus being hidden by the larger target echo. Spotting in bearing will be feasible, as the splash does not last long enough to permit antenna to be trained on it accurately.

8. Ranging on distant land up to 150,000 yards.

V. LIMITATIONS OF RADAR EQUIPMENT

Radar has certain limitations, and certain difficulties may be perienced in its use. It is well to have a good knowledge of t in order that too much will not be expected of any Radar set

A. Rapid development of Radar equipment without extensive te

B. The effectiveness of Radar is largely dependent upon the skill a experience of the operator. Operating experience shows that at lea 50 hours is required before an operator begins to acquire any degree proficiency, and a much longer period must elapse before he can classed as an expert. A skilled operator should readily be able determine the nature of a target whether aircraft or surface vesse and to distinguish between a "single target" and a "few," a "few" an "group." The latter is closely tied up with the inherent resoluti of the Radar which varies for the different models. While visu acuity is of importance, judgment is actually the deciding factor expertness.

Constant watchkeeping imposes a great strain on operators, espe ially when counter radio direction finder (RDF) measures are be employed. Experience indicates that half an hour is the longest per an operator can watch the range scope at any one time. Watches shou therefore, be two hours long, and two operators should be assigned each watch. They should alternate as actual operator every half-ho On fire control equipment the one who is not operating can act trainer.

C. The possibility of a ship's position being disclosed to the en by radio direction finder (RDF) bearings being taken of its Rad transmissions must never be overlooked. The danger of such detect may, however, be minimized by the use of appropriate counter R measures.

Radar transmissions on the higher frequencies are less suscepti to interception by radio direction finder receivers than are those the lower frequencies. Unfortunately, most of the sets we have service now can probably be detected by shore based RDF sets or special shipboard RDF sets on the larger ships. It is quite like that accurate bearings on Radar transmissions can be taken up to miles and, on some occasions, with less accuracy and certainty greater ranges. A point which must always be remembered is that Ra transmissions can be intercepted at much greater ranges than those which echoes can be obtained. This is an advantage both to our forces as well as those of the enemy.

D. It is believed possible for certain types of aircraft to ta bearings on Radar transmissions.

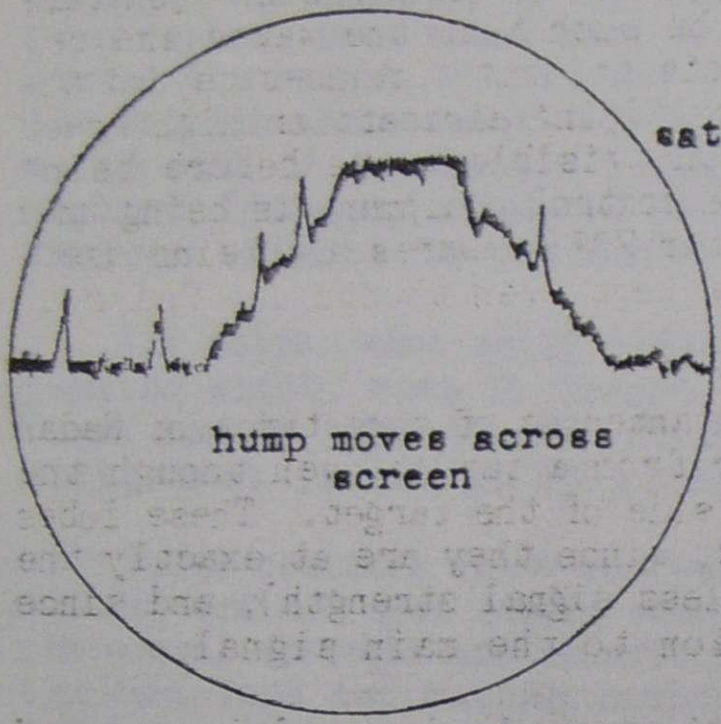
E. The scarcity of identification equipment on our own ships a planes at the present time gives rise to one of the greatest proble

F. Since Radar operation depends on a clear radio "line of
between the Radar antenna and the target, the range at which
may be detected is dependent on its height above the horizon.
occasions atmospheric conditions may be such that the waves
fracted and the Radar will detect objects at long distances be
horizon). It is quite possible for low flying aircraft or hig
surface craft to approach to within the visible range befor
detected by Radar (not so likely if fire control equipment is be
for searching), particularly when counter RDF measures are bei
It is essential that a good lookout be kept even though the R
being used.

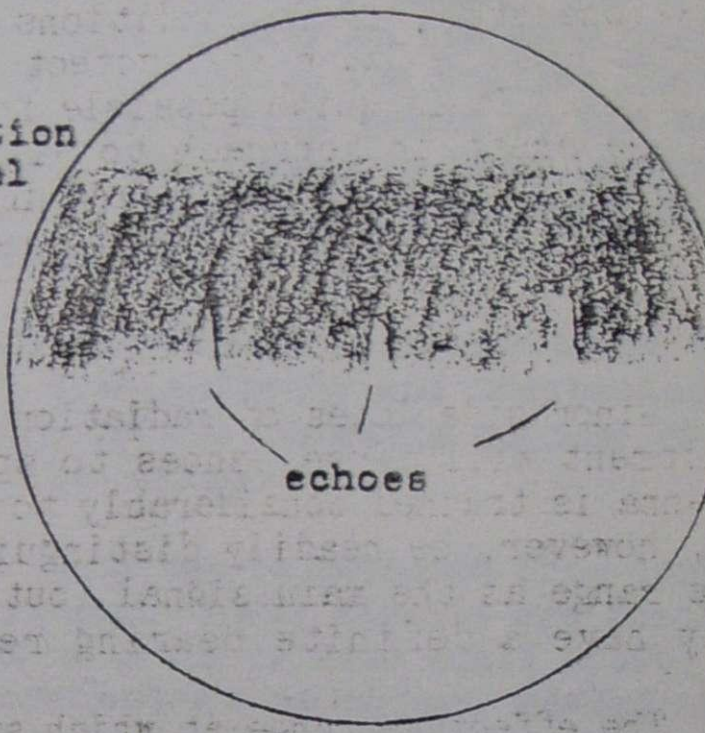
G. Minor side lobes of radiation from antennas of some types
equipment will cause echoes to appear from a target even tho
antenna is trained considerably to one side of the target. The
may, however, be readily distinguished, since they are at exac
same range as the main signal (but of less signal strength), a
they have a definite bearing relation to the main signal

H. The effective range at which submarines can be detected by
Radar is comparatively short, because of the small reflecting
which such targets present. Reliable signals may be obtaine
about two miles on surfaced submarines, although on several oc
they have been detected at as much as nine miles. Tests of R
with a submarine target indicate that detections may be made at
of about one mile when the target is at periscope depth (pe
showing), and at 1-1/2 to 4 miles with the conning tower s
Present equipment is used to the best advantage against sub
during periods of reduced visibility.

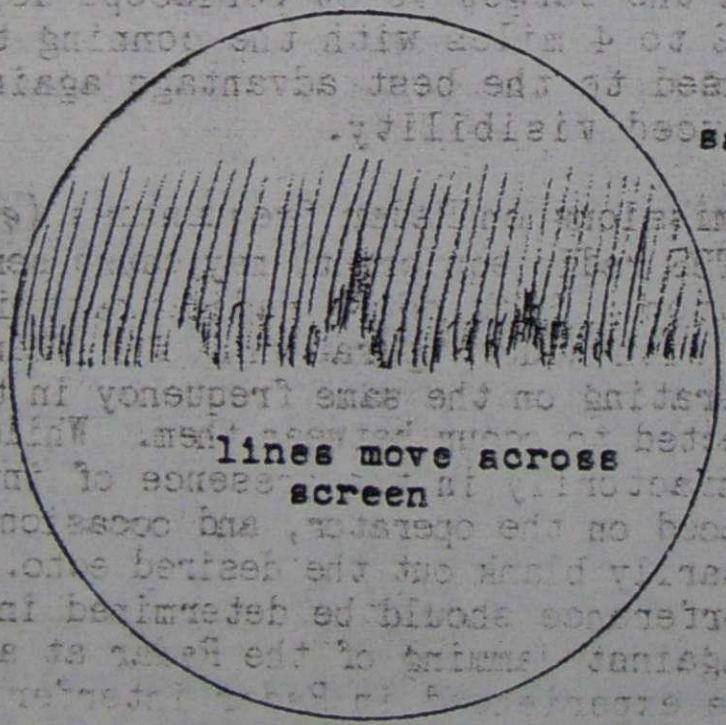
I. Local radio transmissions on Radar frequencies (*e.g.*, the
beacon in carriers and TBS radio equipment) may cause serious i
ence with Radar operation. High power radio transmissions
vicinity may interfere with Radar operation. And where ther
number of Radar sets operating on the same frequency in the same
interference may be expected to occur between them. While it is
possible to range satisfactorily in the presence of interfere
additional strain is placed on the operator, and occasionally th
fering signal may momentarily blank out the desired echo. The ex
and extent of such interference should be determined in each s
steps taken to insure against jamming of the Radar at a vital
No difficulty *should* be experienced in Radar interfering wit
communication circuits, because our communications receivers
designed as to preclude the occurrence of such interference. Rad



FM-CW jamming on instantaneous screen



FM-CW jamming on long persistence (CRO) tube



J. It is known that the enemy has equipment capable of jammi
Radar and rendering it entirely ineffective. When such jamming
the only remedy is to shift to another Radar set on a differen
quency. For example, if the ship control Radar were jammed, one
fire control sets would have to be brought to bear on the same t
During the recent *SCHARNHORST-GNEISENAU* action in the English C
the British shore-based Radars were so effectively jammed by the
as to make it impossible to use them. The enemy, in this inst
employed frequency modulated CW signals. The probable appearance
various effects is indicated on page 12.

All ships, when using Radar, must be constantly on the alert
jamming which, when it occurs, will come suddenly and unexpect
Steps must be taken to meet it instantly if the favorable outcome
engagement is not to be given to the enemy.

K. False contacts which confuse the issue may be obtained from i
clouds, and are most common around mid-day. These signals are pr
the signal strength approximating that of a tug or some small craf
the bearings and ranges indicate contact on an object moving
definite course at a definite speed. Contrary to expectation,
bearings can be taken on the signal, indicating a concentrated m
ionized air. These contacts are very hard to prove false. In
cruising during good visibility they present no problem for it is
determined that there is no target, and rational means can be ut
to find the cause; but at night, steaming at darkened ship, the
factor does not permit the determination that the signal is defi
false. Action must be taken immediately by ship control before c
mation can be ascertained. False contacts on clouds may be dete
by:

(1) Coordination of the plotted course and speed of the targe
the aloft wind data.

(2) Use of an FC or FD Radar to obtain position angle. I
position angle is above the horizon and the target speed is less t
knots, it is reasonable to assume that a cloud contact has been
This check, however, requires time, for it is difficult to get
Radar on the target, and in most cases it is impossible to get
Radar signal from elevated targets beyond 6,000 yards. The FD sho
much better than the FC for this purpose.

L. Additional confusing echoes may be obtained from distant m
ains, wave tops in a heavy sea, and possibly from enemy Radar t

N. It is possible and comparatively easy for the Radar operator range on the wrong target, and this problem is of vital importance wh planes are operating in the vicinity of surface ships. If the range the plane is near the range to the ship, it is likely that the operat will obtain a range to the plane. It is considered advisable, theref where possible, to check the range by an estimate from the spotte

Similarly when an attacking formation, which has been tracked f some time, breaks up, much confusion may result because of the dif culty of deciding which target to follow with the Radar.

O. Ice conditions prove very detrimental to Radar operation, for n only does the equipment fail to function properly when the antenna covered with ice, but ice covered targets give a very weak signal often cannot be detected at all.

P. Much of the effectiveness of Radar is lost unless orders and d from Radar contacts can be transmitted to the ships concerned i minimum of time. A suitable vocabulary is necessary for rapid tra mission of Radar information and instructions on the Radar warning ne

VI. THE RADAR TACTICAL ORGANIZATION AND ITS FUNCTIONING

With elementary knowledge of the capabilities and limitations Radar it is possible to consider the Radar Tactical Organization and it should function. This section is based directly on the CINCPAC Te ative Radar Doctrine of 6 October, 1941. Briefly, the Radar Tacti Organization consists of a number of Radar Guard Ships, a Radar Cont Officer, Fighter Direction Officer, Radar plotters, and operators. duties of the Fighter Directing Officer and his own organization will taken up more completely in the section on Fighter Direction f Aircraft Carriers.

A. RADAR CONTROL

1. DUTIES

Radar control should, as a rule, be a function of O.T.C. who sho

(a) Assign sectors of Radar responsibility if other than a stand disposition has been ordered.

(b) Maintain a continuous plot of all warning net informat

(e) Advise Radar Guard Ships of known movements of own or e
or surface craft. Normally, the O.T.C. will not transmit curre
information of enemy aircraft in the vicinity, since that is the
of Commander Air (FDO).

(f) Order any guard ship to shift target, search 360°, or
position of friendly fighters as necessary.

2. RADAR CONTROL RELIEFS

The sequence of Radar Control reliefs should be the same as t
of tactical command. Relief Radar Controls should be prepared
over at any time.

3. GENERAL

Whenever possible at night or during periods of low visibili
watches should be maintained in the O.T.C.'s ship only, since
Radar policy is more easily controlled, and signaling and delays
viated. This, of course, presumes that one Radar is sufficie
thorough search; a condition which will exist rarely.

When a target has closed sufficiently for fire control Radar e
to be brought into operation against it, Radar Control should d
one or more ships to continue keeping a warning watch as a pre
against attack by additional enemy units.

B. RADAR GUARD SHIPS

1. FUNCTION

The reason for detailing Radar Guard Ships is that the entire
may be more quickly and thoroughly searched by a number of shi
searching a definite sector than by one ship searching the enti
Generally, however, an all-round search by each guard ship is pre
but a sector watch is desirable as providing particular security
low flying aircraft or high speed surface craft, or when the p
direction of an enemy approach is known.

2. ASSIGNMENTS

(a) In each assigned sector of Radar responsibility there sh
established a sector Radar Guard Ship.

(b) When a sector of Radar responsibility contains more t

(d) Radar guard Ships should normally be stationed in or beyond outer screen. Whenever possible they should be within easy visual naling distance. If ships are in line ahead, the Guard ship should slightly out of line.

3. DUTIES

(a) Conduct continuous search of assigned sector employing appro ate counter RDF measures or such Radar policy as Radar Control may or

(b) When a new contact is made, transmit an initial report to R Control. The extreme importance of transmitting this initial re *immediately* not only to Radar Control but to all non-Radar ships as cannot be overemphasized. During recent operations in the Pacific, R warnings of approaching aircraft were usually so late in being deliv to non-Radar ships as to negate the value of the Radar installat

(c) Track and plot each contact in own sector. When data obtaine sufficient to determine enemy intentions, transmit amplifying rep from which the F.D.O. can contact enemy with own Radar, and O.T.C. base orders and issue "Alerts" to the ships in the force. If poss the amplifying reports should include the number of enemy units, bea and distance from Fleet Center, course, speed, altitude, and time. first amplifying report should be made at the earliest possible mo even though the information is not entirely complete. Subsequent am fying reports need be made only when changes in major variables (cou speed, altitude) occur. Although it is desirable to report the bea and distance of the target from Fleet Center, it will usually be convenient, and save more time to report bearing and distance from reporting ship. Special care must be taken to report the corr bearing. In one recent action enemy planes were reported (incorrec as approaching on a certain bearing, but since they actually came fr different direction the value of the Radar report was completely nu fied.

(d) When Radar Guard Ships are making sector searches some provi must be in force so that when one ship makes a detection and comme tracking, its sector will not remain unguarded. There are numerous in which such a system can be worked out depending on the number and position of the guard ships, and considerable latitude should be all each Radar Control in working out a method which will best suit his ticular situation. Some possible methods are:

(1) Each Radar Guard Ship searches entire 360° All guard

(2) Radar Guard Ships employ sector searches, while fi
Directing Ship searches the whole circle. When a target enter
sector overlap between adjacent sector guard ships, the guard ship
sector the target is leaving notifies the guard ship whose sector
entering. The latter notifies the former when it has located the t
and assumes responsibility for it, and the former does not relinqui
target until this notice is received. This system will probably
the best in most cases.

(3) Radar Control Ship takes over search of the sector or
ally covered by guard ship which has made a detection and is now tr

(4) When one Radar Guard Ship makes a detection the two
covering the sectors on either side, enlarge their sectors so as t
clude that originally covered by the ship making the detect

(e) Notify the sector commander or Radar Control in case of ca
or Radar activity beyond own capacity to track and plot.

C. FIGHTER DIRECTING SHIP

1. DUTIES

Fighter Direction should normally be a funtion of Commander Air
should:

(a) Maintain a continuous plot of all Radar information affecti
operations.

(b) Evaluate plot and transmit appropriate "Alerts" of impe
air attacks.

(c) Launch combat patrols on order, or (unless specifically or
to the contrary) without order when definite Radar contact with
aircraft is obtained.

The number and disposition of combat patrols should be a
discretion of Commander Air, but the section designations of pa
launched or recovered should be communicated to Radar Control, R
Radar Control, and the Radar Guard Ships.

(d) Utilize own Radar to the best advantage to supplement inform
from Radar Guard Ships, and transmit evaluated information fro
Radar when it is pertinent to the general tactical situatio

2. TYPICAL SEQUENCE OF FIGHTER DIRECTOR RELIEFS

(a) Commander Air.
(b) Carrier Division Commanders in order of seniority.
(c) Carriers in order of seniority.
(d) Air Task Group cruisers in order of seniority.
(e) Battleship Division Commanders in order of seniority.

Relief Fighter Directors will be prepared to take over at any t

D. OTHER RADAR SHIPS

1. Normally ships not detailed as Radar Guard Ships may use t Radar within the limitations of the Radar policy which is in effec the time. In their case reports should be made only when guard s fail to report in accordance with the system in force within a reason length of time.

2. If no Radar Guard Ships have been detailed, ships should re any unidentified contact which might endanger the fleet.

3. When particular security is required, orders should be given only Radar Guard Ships and Radar Control are to transmit. The o ships may, however, keep a receiving watch. There should never be restriction on transmission when air or surface attack is known t imminent, and it is obvious that the enemy is aware of our own posit

E. RADAR COMMUNICATIONS

1. FUNDAMENTAL CONSIDERATIONS

Rapid communication among vessels of a group is essential bot report Radar contacts and exercise Radar Control. In actual prac visual, radio-telegraph and radio-telephone have been tried. Only ra telephone has proved sufficiently rapid where attacking aircraft been involved. Visual should not be used at night and often canno used in reduced visibility.

Once it has been decided to accept the risk of disclosure or in ception necessary to use Radar, a common radio-telephone circuit sh be available to all ships operating in a disposition. The frequency power used for this circuit must be such that the probable range u all conditions will be less than the direct transmitting range of Radar. Super-frequency equipment, similar to Model TBS, using *low* po

Therefore, in order to coordinate Radar, disseminate informatic when necessary, maneuver the disposition; it is essential that Mod or its equivalent be installed in large vessels such as carriers, cruisers and battleships as soon as possible. This has been autho A task force commander is usually in a large ship which is accompar smaller ships. It is necessary that large ships, particularly flag be able to work super-frequency radiophone with small ships or es Only thus can proper coordination be effected rapidly with a m chance of enemy radio detection or interception.

It is desirable to use frequencies above 250 mcs. However, equipment will not be available for some time, some immediate arran is needed. Almost all small vessels are already equipped to us quencies of from 60 to 80 mcs. Therefore, only a relatively small of additional TBS or similar equipments would be needed. During th few years, due to the present sun spot cycle, frequencies above 6 will probably be relatively free from sporadic ionized layer refle Refraction in the lower atmosphere, known to extend the range of 6 transmissions to over 100 miles can be greatly reduced by using low

Thus for all practical purposes, TBS equipment on low power used on 60 to 80 mcs. for invaluable short range communicatio limited assurance that interception by enemy surface craft over 40 away is improbable. Interception by specially equipped enemy ai is, of course, possible at greater distances. But if low power wi antennas is used, the chances of interception over the horiz remote. Multiple whip antennas at convenient points just below level are needed to avoid blind spots when using low antennas. tive ranges to surface craft can be reduced to 10 or 15 miles, if d

2. WARNING NET

Warnings of impending attacks should be transmitted *immediately* Warning Net by the Radar equipped ships designated for this duty O.T.C. All ships should insure that the Radar Warning Net Circu accurately tuned and that the information received on this net is c icated instantly to the Captain and Gunnery Control.

In addition to traffic assigned to the warning net by U.S.F. following communications should be handled on this curcuit:

(a) All reports by Radar Guard Ships.

3. FIGHTER NET

The following communications should normally be handled on t circuit:

(a) Orders to combat patrols.

(b) Reports from combat patrols.

(c) Orders from Fighter Director to carriers to launch or rec patrols.

(d) Reports from carrier relative to launching or recovering patr etc. (To include section color designations).

4. CIRCUIT INSTRUCTIONS

(a) Separate circuits should be provided for Fighter Net and War Net in order to handle the volume of traffic expected during major activity against a large fleet disposition. In smaller dispositions during periods of minor air activity, these two communication circ may be combined on a common frequency by O.T.C. Traffic on both circ should be broadcast without receipt or acknowledgment, except that craft units will acknowledge for receipt of orders.

(b) Circuits should as a rule, be manned as follows, available eq ment permitting:

	FIGHTER NET		WARNING NET	
	TRANSMIT	RECEIVE	TRANSMIT	RECEIVE
O.T.C. (RADAR CONTROL)	-	X	X	X
RELIEF RADAR CONTROL	-	X	X	X
FIGHTER DIRECTOR	X	X	X	X
RELIEF FIGHTER DIRECTOR	X	X	X	X

5. FORM OF RADAR REPORTS

To facilitate plotting, Radar reports should be made in the follo form:

(a) Type and number of targets; that is, air or surface, one, (2 to 10), many (over 10).

(b) True bearing from Fleet Center. For convenience and speed t

*(d) Course (true).

*(e) Speed (knots).

*(f) Altitude (if approximate, use "low," "high," "very h

*(g) Zone time of the above data.

(h) Additional pertinent information, if any.

(i) Call of originating ship.

* These items should not be required in initial reports. As
them as can be determined without undue delay should be include
amplifying report which is to be used as a basis for interce

Examples:

Initial report by Radar Guard Ship:

"FEW BANDITS, TWO ONE ZERO, FOUR SIX, CAST TWO

Amplifying report by Radar Guard Ship:

"FEW BANDITS, ONE EIGHT FIVE, THREE ZERO, O
ZERO, ONE FOUR ZERO, VERY HIGH, ELEVEN FOU
CIRCLING FLEET TOWARD BEARING OF SUN, CAST TWO N

6. VOCABULARY

Standard phraseology should be used by all Radar operators in re
ing information to Radar Plot and other control positions. The v
ulary used in Fighter Direction and on the Radar warning and fi
nets should be used whenever possible. In this way all personnel
cerned with handling Radar information will use common terms, brie
clear, which will leave no doubt as to the information conveyed.
need for a uniform, brief, and clear form of exchanging Radar inf
tion rapidly cannot be over-emphasized.

If desired, the more important phrases could be given in example such as:

RADAR OPERATOR REPORT	MEANING
"FEW BANDITS, ZERO FIVE FIVE, DISTANCE THIRTY-FIVE AWAY."	"Two to ten enemy aircraft, bearing 055 true, distance 35 miles going away."
"BLUE FIGHTERS, ONE FIVE ZERO, DISTANCE THIRTY."	"Our blue sections of VF, bearing 150 true, distance 30 miles."
"LARGE BANDIT, TWO FIVE ZERO, FADING AT FIFTY."	"The Radar signal from a large group of enemy aircraft which is being tracked on bearing 250 is fading at 50 miles indicating the edge of a null band."

FIGHTER DIRECTOR'S ORDERS TO RADAR OPERATOR	MEANING
"TRACK BANDIT ONE FIVE ZERO, DISTANCE THIRTY."	"Follow the enemy aircraft, 150 degrees, 30 miles, making reports about every 15 seconds or when signal fades or re-appears."
"TRACK FOR INTERCEPT, BLUE FIGHTERS AND LARGE BANDIT THREE ZERO ZERO DISTANCE FORTY."	"Take ranges and bearings, alternating between own blue fighter section and enemy aircraft group described. Report as rapidly as practicable."
* "SEARCH FROM ZERO ZERO ZERO TO ONE FOUR FIVE."	"Sweep search the sector 000°-145° true."

** Note: Always indicate sector in a clockwise direction.*

7. VISUAL COMMUNICATION

Visual signals to combat patrols are very slow and are practicall useless when enemy aircraft are approaching the fleet. The short reli able range of most of our Radar warning sets requires immediate actio

Also some latitude should be allowed ships in the distant screen
radio for an initial report of a number of enemy aircraft approa
the fleet, if the visual system is not considered sufficiently r
The promptness with which an initial report reaches Commander Air
often determine whether there is one or several sections of VF ava
to intercept the enemy, and mean the difference between a successf
a missed interception.

8. FREQUENCY OF RADAR REPORTS

No definite rule can be laid down for how often reports shou
made. The governing consideration should be that communication ci
are not overloaded and that sufficient reports are made to insure
plots being kept in other ships.

F. RADAR PLOT

1. FUNDAMENTAL CONSIDERATIONS

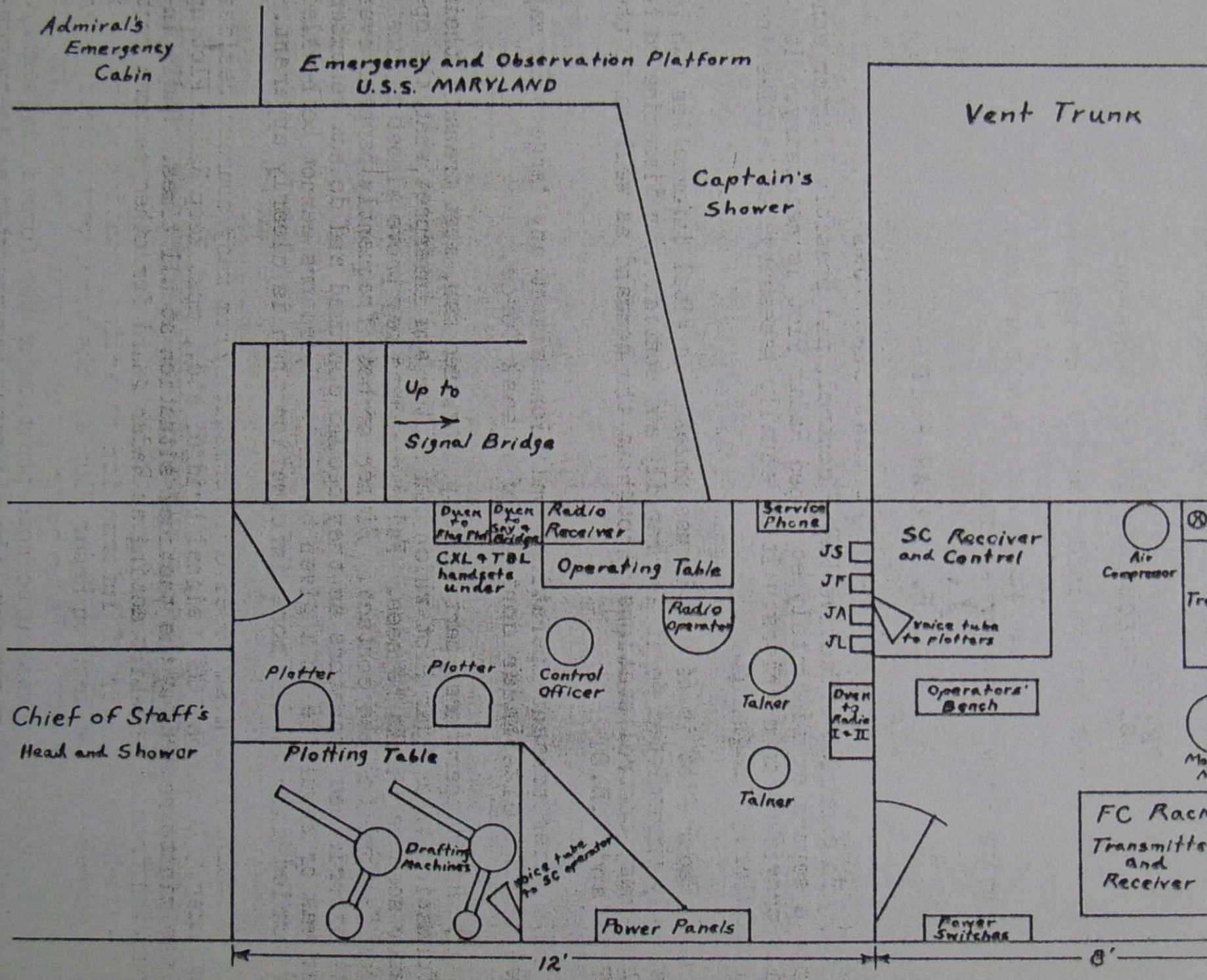
(a) To exercise effective Radar control, and possibly Fighter
trol, a separate, adequately equipped Radar Plot is necessary.
being provided for carriers. It is equally necessary for battles
particularly flagships.

(b) Radar Plot is of little use unless the vital information c
instantly transmitted to it and rapidly and continuously dissemina
all gunnery control stations throughout the command as well as t
O.T.C. and F.D.O.

(c) Under present operating conditions almost any large shi
have to exercise Radar control of a task force.

(d) Radar operators, particularly untrained men, must transmit
information to a Radar Plot which can filter and interpret what th
erator sees or thinks he sees. False contacts may prove almost as
ly as failure to make contact. Either or both frequently happen,
with experienced operators as they become confused and do not rem
what was or should be on a given bearing. Operators cannot be he
or hurried into giving more information than is clearly appar

(e) Radar Plot must receive information from many sources be
own Radar. Lookouts, OOD, signal bridge, etc., must keep Radar Pl
to the minute regarding the tactical situation at all times. Radi
formation from other ships acting as Radar guard for other sectors
be plotted. *Every bit* of information regarding location of ow


Admiral's Emergency Cabin
Emergency and Observation Platform U.S.S. MARYLAND
Vent Trunk
Captain's Shower
Up to
Signal Bridge
Down to Flag Plot
Down to Sky Bridge
Radio Receiver
CXL & TBL handsets under
Operating Table
Service Phone
SC Receiver and Control
Air Compressor
JS
JF
JA
JL
Radio Operator
voice tube to plotters
Plotter
Plotter
Control Officer
Talker
Talker
Down to Radio I & II
Operators' Bench
Chief of Staff's Head and Shower
Plotting Table
Drafting Machines
voice tube to SC operator
Power Panels
Power Switches
FC Rack
Transmitter and Receiver
12'
8'

RADAR PLOT

(f) The officer in charge of Radar Plot and control has tremendo responsibility. He must be experienced in tactics as well as Radar

(g) Repeated attempts to keep a complete Radar Plot in Flag Plot Chart House have been unsatisfactory for many reasons; interference noise, confusion, delay, etc. Really successful operation has not be obtained with any installations so far used, except for short perio where everything else in Flag Plot and all maneuvering was stopped restricted.

(h) Thus the proposed system illustrated on page 24 has been evolv and tested by actual operation.

(i) In disseminating and receiving information in Radar Plot, the lo speaker communication phone or voice call equipment ("Donald Duck") most essential. It is most needed during cruising conditions, prior General Quarters. Quick reports and questions, direct from officer officer, are essential to decide on action when a contact appears to developing. Officers are too greatly restricted if they attempt to we telephones indefinitely. Talkers are *most* unsatisfactory, particular green men who must be used. At General Quarters, the inter-phones a backed up by sound powered phones, thus if the system goes out aft commence firing, no confusion results. In a modern blitz, the most i portant communications are those required before commence firing. T fundamental tactical principle must be applied before commence firin the first few salvos frequently determine the results of the action. Mo ships are using inter-phones of one type or another and all who are usi them find them invaluable.

2. GENERAL CONSIDERATIONS

In view of the fact that the foregoing provisions cannot be effect immediately in all the larger ships and probably never in the small ships, the following general points are presented:

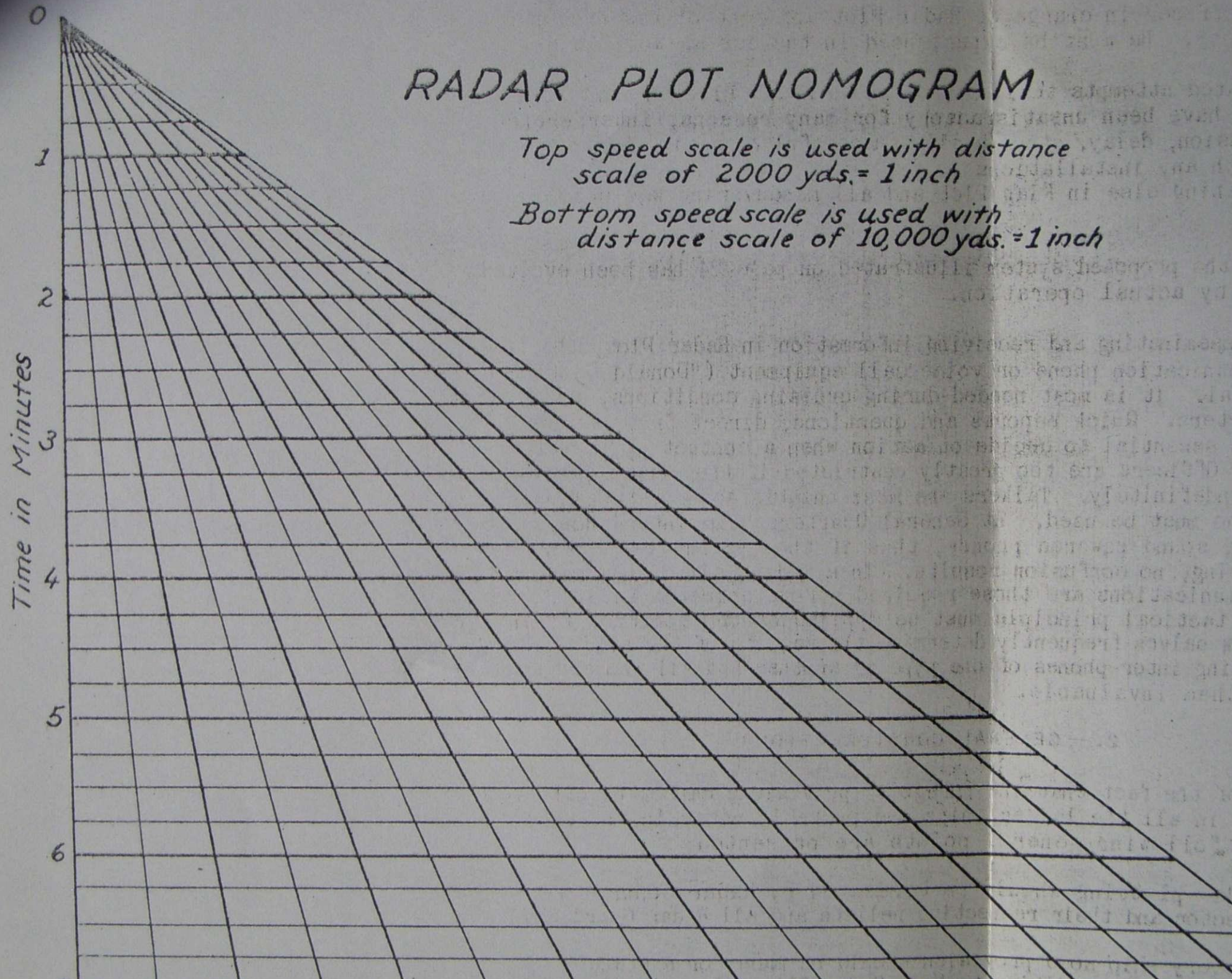
(a) Radar plotting should be conducted by Radar Control (OTC Fighter Director and their respective reliefs and all Radar Guard Ship

(b) In every ship some provision should be made for a standby Rada Plot. In one ship in addition to Main Radar Plot, plots are located the chart house and Main Battery Plotting Room. These plots are kept mooring boards by seamen.

RADAR PLOT NOMOGRAM

Top speed scale is used with distance scale of 2000 yds. = 1 inch

Bottom speed scale is used with distance scale of 10,000 yds. = 1 inch



3. RADAR PLOT PROCEDURE

(a) The Radar Plot should be in polar coordinates, origin at F Center, radii in true bearings, distance in nautical miles.

(b) Since the Fleet Center is normally in motion, the relative m ment plotting system should be used. With aircraft cruising speeds to fifteen times fleet speed, the relative plot will differ but li from a navigational or geographical plot for aircraft work. In plo surface ships with speeds on the order of one or two times fleet s the plot must be handled in relative movement to predict time and of contact. The 20" mooring board (H.O. 2665) is considered the sma satisfactory plotting sheet. It will be convenient to plot the i disposition to scale on a pivoted overlay which can be rotated wit fleet axis.

(c) For Fighter Direction, a special plotting board and plotting gram has been prepared by the Fighter Director School, Norfolk. Sa have been shipped to each carrier. The board measures about 40 i square and is adopted for use in a tilted position. Additional rol an improved plotting sheet are being printed by the Hydrographic Of

(d) Time is the essence of successful Radar use. The developme every prospective Radar Control, Fighter Director, and Radar Guard of standard plotting procedures to make the best use of available i mation is absolutely necessary. Dead-time errors on the order o minute are sufficient to cause a missed fighter interception, since craft moving in different directions at high speed may travel a rel distance greater than the range of visibility. Interceptors shou directed to a predicted meeting point.

4. RADAR PLOTTING AIDS

(a) NOMOGRAM

Two scales are used on the mooring board; one of 2,000 yards t inch and one of 10,000 yards to an inch. Points plotted on the la scale are enclosed in a small circle to identify them. An align nomogram (as illustrated on page 26) engraved in a piece of cellu acetate is employed to determine relative speed from the points plo The nomogram is placed over the plotted points and, depending upo time interval elapsed, relative speed is read directly. The use of device makes possible the determination of target course and speed w a few seconds after receipt of the second bearing and range on a ta

(b) PEG BOARD

In one ship the Radar plotting officer transmits all contacts bridge over the JA phone and, as soon as a contact is developed the bridge the estimated course and speed of the target. This in tion is also simultaneously received by sky control. In additio sky control officer has a JS talker who keeps him informed contacts. This JS talker keeps pegs set in a peg board (illustra page 28) showing all aircraft in the vicinity. The director c officers are kept informed by the computer operators in Plot ov 1JP, 2JP, 3JP and 4JP phones. A large blackboard showing the pos of all aircraft within 30,000 yards is kept in Plot for the infor of the computer operators.

5. TIME-BEARING OF RADAR PLOT

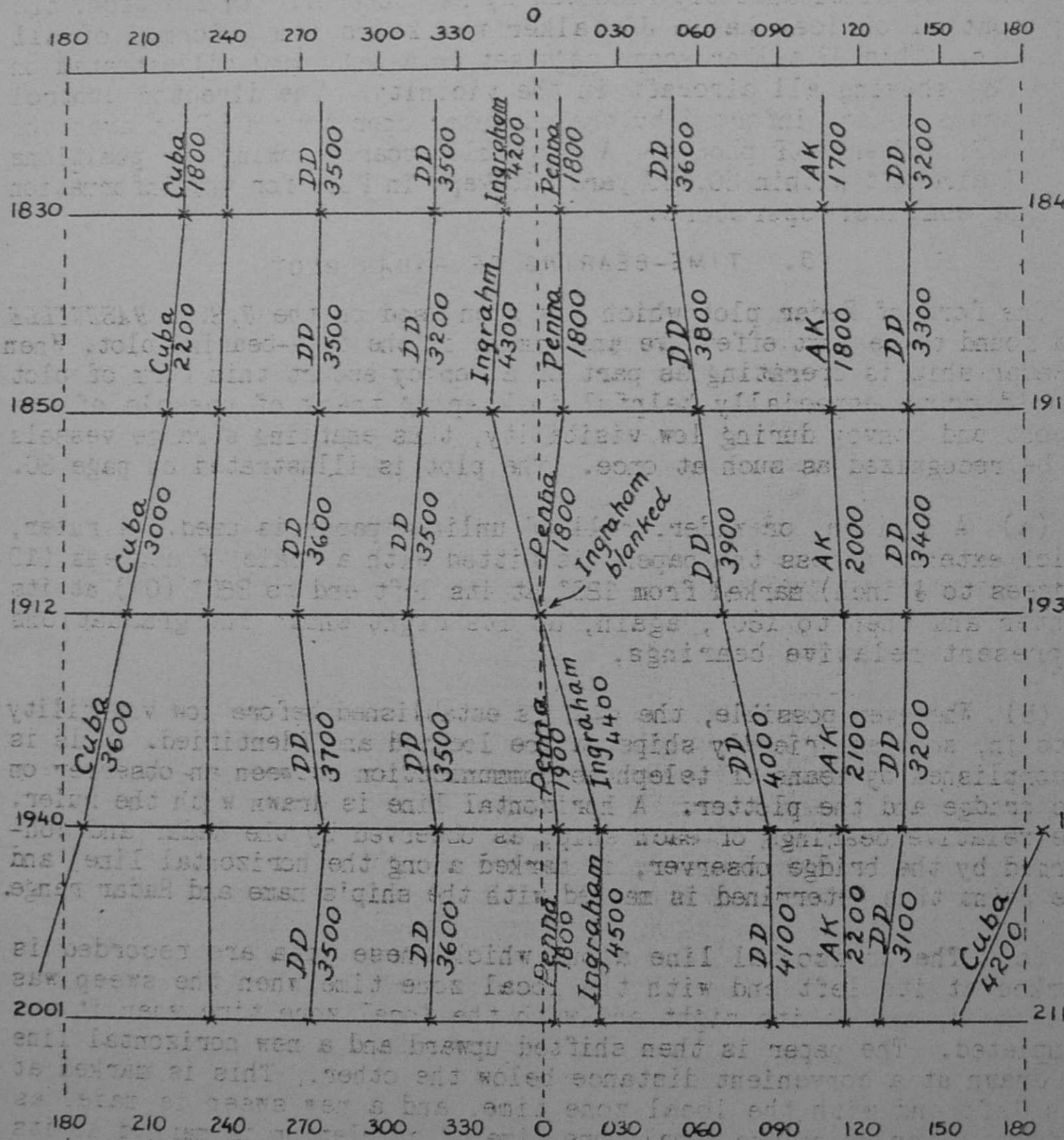
One form of Radar plot which has been used on the *U.S.S. NAS* and found to be most effective and simple is the time-bearing plot a Radar ship is operating as part of a convoy escort this form o should prove especially helpful in keeping track of vessels escort and convoy during low visibility, thus enabling strange v to be recognized as such at once. The plot is illustrated on pa

(a) A 20 inch, or wider, roll of unlined paper is used. A which extends across the paper, is fitted with a scale of degre degrees to ½ inch) marked from 180° at its left end to 360° (0°) center and then to 180°, again, at its right end. The gradu represent relative bearings.

(b) Whenever possible, the plot is established before low visi sets in, so that friendly ships can be located and identified. T accomplished by means of telephone communication between an obser the bridge and the plotter. A horizontal line is drawn with the The relative bearings of each ship, as observed by the Radar an firmed by the bridge observer, is marked along the horizontal lin the point thus determined is marked with the ship's name and Radar

(c) The horizontal line along which these data are record marked at its left end with the local zone time when the swee commenced, and at its right end with the local zone time when completed. The paper is then shifted upward and a new horizonta is drawn at a convenient distance below the other. This is mar its left end with the local zone time, and a new sweep is mad before, after which the local zone time of completion is marked right end.

EXAMPLE OF TIME-BEARING RADAR PLOT



One difficulty, likely to be encountered even with technically Radars, particularly when the convoy is large, results from the off by large convoy vessels of outlying screening destroyers, whi become unblanked due to gradual changes in relative positio destroyers, thus suddenly appearing on the screen, are likel reported as strangers. The best safeguard against this is a c made initial sweep, during good visibility, so that cases whe ships are likely to blank off small ones can be recognized in The Radar operator also requires a plan view of the whole dis with ships in their prescribed positions for checking.

VII. OPERATIONAL USE OF RADAR AT SEA

A. FACTORS AFFECTING THE USE OF RADAR AT SEA

1. Danger of enemy interception of Radar transmissions a direction finder activity on same. The constant presence of thi may necessitate the curtailment of own Radar transmissions to so

2. Probability of attack by aircraft or of encountering enem ships. This will depend upon:

(a) Operation upon which own force is engaged.

(b) Proximity of enemy air and/or naval bases.

(c) Intelligence of enemy intentions, dispositions or

3. Visibility conditions depending on weather and time

4. Maintenance of equipment. Shutdowns for routine maintena must be fitted in with the current operating requirements. In life may be prolonged by relying on lookouts during good vis

5. Cognizance of the fact that the use of Radar enablea AA personnel to relax somewhat. This is considered to be of pa importance during the summer in northern waters where long hour light prevail.

B. COUNTER RADIO DIRECTION FINDER (RDF) MEASURE

As has been mentioned before, it is quite possible for the intercept our Radar transmissions. In addition it is possible to obtain bearings on our ships by means of radio direction

effective. Negligence in their use, even for a short time, is likely t compromise the position of our own units.

The general rule for counter RDF measures is to use the Radar tran mitter for the shortest possible time consistent with a reasonably ef fective search. The antenna should be kept training at maximum spee when a target is not actually being investigated. In addition th search sector should be changed between each transmission when pract cable.

No specific directions for counter RDF measures can be given, b Radar personnel should be allowed considerable latitude in working o effective measures.

C. RADAR WATCHES

1. WARNING

A warning watch should be kept continuously to warn of enemy aircraf and particularly during low visibility to warn against surface ship The exact nature of the warning watch will depend on the current si uation.

(a) TRANSMITTING WATCH

(1) *Using counter RDF measures.* This is the type of warning watc which will be most generally used.

(2) *Not using counter RDF measures.* This type watch should b employed only when an attack is known to be imminent, or when it is ob vious that the enemy is aware of our position.

(b) RECEIVING WATCH

(1) There is some desirability of keeping a receiving watch with th Radar at all times when not transmitting, on the chance of interceptin enemy Radar transmissions. This may be done at ranges much greater tha those at which it is possible to obtain echo signals and it is possibl to take bearings on such intercepted signals. Unfortunately in cannc be predicted what form such intercepted transmissions will take on th screen of the cathode ray tube, but it is possible to distinguish the audibly by a headset plugged into the receiver.

frequency, even though they receive no echo, at ranges up to 60,
80,000 yards. The signal strength reaches a maximum when the ante
trained on the bearing of the target. The use of the external sw
stop the signal received is a great help in gaining accuracy when
the receiver as a radio direction finder. The bearing is thus
mined accurately and an estimate of the range can be made by noti
height of the received signal and the sensitivity adjustme

Although no information is available, it is thought possible
ploy Radar as a radio direction finder when the enemy renders or
Radar operation ineffective by jamming. If the transmitter is s
and some means can be provided to use the incoming jamming signal
external synchronization voltage for the oscilloscope, it shou
possible to train the antenna to the bearing which gives maximu
ming signal strength and so to get a rough determination of the
tion of the enemy.

When an interception is made on a receiving watch, the ope
should switch immediately to a transmitting watch, preferably
counter RDF measures. The chief advantage of the receiving wat
that it may be used even when, for purposes of security, it
deemed wise to use the Radar transmitter.

(C) COMBINATION RECEIVING AND TRANSMITTING WATCH

Under certain conditions this type of watch may be desirable.
it is ordered, the receiving portion should be carried out for as
a time as possible consistent with an all-round search, and shou
exceed two minutes. Otherwise low flying aircraft or high speed s
craft may approach undetected.

2. FIGHTER DIRECTION WATCH

This watch should be kept in the Fighter Directing Ship at all
when a combat patrol is in the air or standing by on deck.

3. STANDBY FIGHTER DIRECTION WATCH

This watch should be kept by the standby fighter directing
whenever a combat patrol is in the air.

4. FIRE CONTROL WATCH

Therefore very careful judgment must be exercised in determining t proper instant for bringing the fire control Radar into operation. Op ators of this equipment must stand by with the antenna trained to t proper bearing, and fully prepared to start transmitting the instant order is given. The operators should be taught that as soon as t detect a change in the normal rate of change of range to become par cularly alert and send accurate ranges more often. This system h proved so successful in one ship that the graphic plotter operator inform the fire control personnel almost immediately of changes in t get course and the direction of such change. The solution of targ course by rangekeepers is based largely on range rate determined by Radars.

D. RADAR POLICIES

1. REASONS FOR ESTABLISHING RADAR POLICIES

A number of Radar policies for the employment of Radar should be tablished to fit the particular conditions under which units of t fleet may be operating. It is the duty of the O.T.C. to promulgate appropriate policy to all Radar ships in the disposition, remembering is desirable to have the fewest possible Radar equipments operating c sistent with efficient and effective gathering of complete informati This will facilitate Radar communications, and reduce the possibility enemy detection of our own Radar transmissions.

Each Radar policy should be assigned a designating letter or num and placed in effect by some order from O.T.C. such as, "Employ Pol BAKER."

2. POSSIBLE RADAR POLICIES

(a) Transmission may take place only when air or surface attack imminent.

(b) Transmission may take place using counter RDF measures, shifti to continuous transmissions if an unidentified formation is detect closing the fleet within some specified distance.

(c) Carry out a sweep, employing counter RDF measures, every t minutes, shifting to continuous transmissions as noted in (b)

(d) No restriction on transmission.

(e) Employ a combination transmitting and receiving watch

VIII. OPERATIONAL USE OF RADAR IN HARBOR

Radar may be used in harbor for the following purposes:

A. AUXILIARY WARNING APPARATUS

1. To provide distant warning in harbors where there is little warning organization on shore.

2. In other harbors to augment the shore warning organizat

3. For fire control purposes during attacks on a harbor.

B. CALIBRATION

Several types of errors exist in all Radar sets, and it is c greatest importance that an accurate calibration of each set be frequently. This can be done best in harbor by ranging on prom landmarks, such as lighthouses or water towers, the distances to are known within 25 yards. To facilitate this procedure special t are being constructed at some anchorages. The detailed instructio carrying out a calibration are contained in Ordnance Pamphlet OR

C. TRAINING

It has been mentioned before that considerable operating experie required before a Radar operator attains a high degree of profic Therefore some sort of training program should be carried out by ship when in harbor where no Radar operating schools are located a Any available planes may be used for tracking purposes, or the fol scheme may be carried out. An ordinary meteorological balloon m used as a target by suspending below it ten dipoles (of correct for the frequency of the Radar set being used) arranged in the form ladder. The dipoles may be constructed of thin metal strips (pref aluminum), twisted so that the upward motion of the balloon will the assembly rotating continuously. This type of target is easily tified by the periodicity of the fading resulting from the rotati the dipoles. This method should never be used when there is any c of the dipole ladder falling into the hands of the enemy, since this they may determine the frequency of operation of some of our equipment.

D. SECURITY

2. When desired to simulate ships at sea.

3. For training purposes to familiarize operators with counter measures.

IX. USE OF RADAR BY SUBMARINES

A. At the present time little or no experience has been gained in use of submarine Radar equipment. The information contained in section is, therefore, based on the results of preliminary test Models SD and SJ.

B. The Model SD Radar for submarines is merely an aircraft war device, and as such employs a non-directional antenna. This means targets may be located only with respect to range. It is possibl operate the equipment and obtain ranges on aircraft when the submarin submerged with the antenna projecting a few feet above the water. the submarine is on the surface planes may be detected up to abou miles, depending on their altitude. Planes below 750 feet ma detected at around 5 miles when the submarine is on the surface, an around 3 miles when it is submerged. Planes at greater altitudes ma detected at from 3 to 10 miles with the antenna only 5 feet out of wa In a few instances the SD has detected surface ships up to 10 miles, as a general rule it will pick up only those surface ships which fairly close.

C. The Model SJ Radar is designed to function as a detector of sur craft and a torpedo director for submarines. It employs a direct antenna which can be rotated through 360°. When perfected it is expe that it will be possible to detect DD's at 8 miles and BB's at 6 m with a range accuracy of 25 yards and a bearing accuracy of ±° (subma on the surface). When submerged with the antenna only a few feet a the water, ranges will be shorter, but no definite information is av able on this at the present time. It should be mentioned that produc of the Model SJ Radar will not begin until some months after the pu cation of this pamphlet.

D. The data on these two types of equipment indicates that just bef surfacing, the submarine should come close enough to the surface to pose both antennas. Remaining at that depth, an all-round sweep of air and sea can be made to determine if it is safe to surface without ing discovered. The periscope will probably be equally effective searching the surface except during poor visibility.

F. It is not known how effective the SJ will be as a torpedo direc but it promises to have a definite advantage at times when it is des to keep the echo-ranging equipment silent. There remains, however, somewhat doubtful risk of the Radar transmissions being intercepte the target ship.

G. In general the same precautions will have to be observed for the of these types of equipment as those already outlined for the set stalled in the larger ships.

H. As more information on the use of submarine Radar is obtained it be included in subsequent revisions of this bulletin.

X. MISCELLANEOUS OPERATING NOTES

A. GENERAL

Operating experience shows that it is not likely that a destroyer approach closer than 16,000 to 18,000 yards to a Radar equipped without being detected. This range is affected by the size of the se sector and rate of sweep. For example: if a single ship is searc the entire 360°, it will take from three to four minutes (possibly m because of contacting ships in own force and checking their positi If a destroyer were approaching the unit at a relative speed of 40 kn in three minutes it would have closed nearly 4,000 yards and might be within gun range of the screen before being detected. This is fur argument for the practice of assigning search sectors to Radar G ships.

B. SWEEPING

Sweeping should be carried out at the maximum speed consistent efficiency and the requirements of the counter RDF measure being empl The following is a rough guide for time of sweeping 360°, but the sence of land echoes will necessarily increase the time of swee

TIME (IN MINUTES) REQUIRED TO SWEEP 360°

	CXAM SC	FA, FC, FDM FH
Taking counter RDF measures	2	4
Not taking counter RDF measures	1	2

2. Other general instructions given to Radar.

3. Time of commence and cease transmission.

4. All initial detections and final observations of a particular t
get. This is important in order that complete operating data may be
tained for each set to determine its capabilities and limitations un
different conditions.

5. All observations of friendly or enemy Radar transmissions w
bearings if possible.

6. All unusual observations made by means of the Radar receive

7. Irregularities in functioning of equipment, and action take

8. Name of operator and time of start and finish of watch.

XI. FIGHTER DIRECTION FROM AIRCRAFT CARRIERS

This section is based directly on the "Tentative Doctrine for Figh
Direction from Aircraft Carriers," dated August 6, 1941. Additio
information obtained from more recent experience has been include

A. OBJECT

The object of Fighter Direction is to provide a means whereby vis
and Radar reports of enemy aircraft may be used to furnish fighte
quickly and accurately with the information necessary to enable them
intercept enemy aircraft.

B. POLICY

It is the policy to detect the enemy aircraft by Radar or by sighti
to correlate the information received from these sources at the figh
Directing Center of the Fighter Directing Ship, and then to pass t
directions to the fighter patrol in the air.

C. LOCATION OF FIGHTER DIRECTING CENTER IN A NAVAL FORCE

1. AIRCRAFT CARRIER AVAILABLE

The Fighter Directing Center of a naval force should be situated in
aircraft carrier, if one is available, for the following reasons

(b) A carrier is best able to tell the position of her own aircr at any moment.

(c) Fighter pilots have practice in communicating with carriers, such communication will be more reliable than if any other ship, wh happens to be operating with the force at the time, should undertake t duty.

(d) The fighters may easily distinguish the carrier from other sh of the fleet. This enables them to judge their position relative to directing ship with greater ease and speed.

2. NO CARRIER AVAILABLE

If there is no carrier present in the naval force, a heavy sh equipped with Radar and situated near the center of the force, should the Fighter Directing Ship.

3. STANDBY FIGHTER DIRECTING SHIP

When an air attack is expected by the fleet or force, there should a standby Fighter Directing Organization in another ship equipped w Radar. The plot of air operations should be kept up to date on t standby ship with all personnel and equipment ready to take over duties of Fighter Direction. When VF are over the fleet, but no att is expected, the Standby Fighter Directing Ship should be capable taking over in about five minutes.

D. FIGHTER DIRECTION ORGANIZATION OF A CARRIER

1. FIGHTER DIRECTING OFFICER (FDO)

The FDO should be stationed in the Fighter Directing Center which w hereafter be called "Radar Plot." Since the FDO must himself trans orders to the combat air patrol, his personality is of the greatest portance. He must supervise the work of the Fighter Directing Organi tion, including the Radar operators, in a manner which creates quiet efficient operation. He must reach correct decisions rapidly, formul his orders, and transmit them to the combat air patrol in a clear, inc ive manner which will hold the complete confidence of the pilo

2. RADAR PLOT

(a) LOCATION

the Air Plot Officer. It is desirable that information contained Radar Plot be readily and visibly available to the Commanding Offic and the Air Plot Officer. It is, therefore, necessary to locate Rad Plot physically contiguous to Air Plot with means of physically sepa ating Radar Plot from this activity, but with facilities for easy a cess or visibility by interested control parties. In carriers speci arrangements are being made to produce a satisfactorily located Rad Plot. For other ships, until more experience is gained, it will necessary to use the chart house or some other space near the pil house as a Radar Plot.

(b) PERSONNEL

Fighter Direction requires quiet and complete freedom for the Fig Directing personnel to concentrate upon the fast moving problem of p ting Radar information and translating it rapidly into precise order the Fighter Patrol. It is, therefore, mandatory to reduce Radar personnel to the minimum for efficient operation, particularly respect to telephone talkers.

3. SOURCES OF INFORMATION

The FDO will generally receive his information from:

(a) The Radar operator or operators.

(b) Other Radar ships by visual or radio. A radio receiver and erator on the inter-ship warning net should be placed near him for purpose.

(c) Reports of enemy aircraft sighted by lookouts in the ship. voice tube or telephone to the lookout station is necessary for t

4. COMMUNICATIONS

Communication doctrine and organization of a naval force should p vide means for all Radar ships present to pass reports of aircraft det ted to the Fighter Directing Ship. The reports should be made by vis until the presence of the fleet is likely to be discovered by the en aircraft, in order that radio silence may be preserved. In case int ception of enemy aircraft becomes essential, the extra speed given radio reporting becomes an important factor in deciding the value radio silence.

E. OPERATIONS IN RADAR PLOT

(c) Three radiomen to monitor two voice channels between the FDO ar the Combat Air Patrol, and the one inter-ship warning net. The FD should himself transmit orders to the combat air patrol by means of a auxiliary microphone located conveniently to his normal position.

(d) One or two talkers as required for communication with pilo house, air defense, main battery control, air plot, etc. It is consid ered that two talkers is the maximum acceptable for Radar Plot, and on is preferable.

(e) Recorder. An electric voice recorder will be supplied to eac Radar Plot in the near future, but this will not replace the recorde whose duties will include keeping the information boards up to date

2. PROBABLE EQUIPMENT REQUIREMENTS

(a) Facilities for positive and rapid communication with Radar operator.

(b) Three remote control operating positions for remote control transmitters for combat patrol and the transmitter on the inter-sh warning net. If practicable, it is desirable that the radio operato be provided with selector switches for remotely controlling the pow output and type of emission of Combat Air Patrol transmitter.

(c) Three receivers.

(d) The telephone circuits in Radar Plot should be reduced as mu as practicable by the use of selective switches and common circuits order to limit the number of talkers to a maximum of two. Since air a Radar Plots will always be adjacent, the telephone circuit facilities Air Plot may in some cases suffice.

(e) Selective switches with handset and headset with selections f the following circuits: JA, 1VG, 2JG, JL, 5JP, JS, JX.

(f) Ship's service telephone (Executive cut-in)

(g) Door and scuttle to Radar Control Room.

(h) Door or hatch and/or viewing screen to Air Plot, Pilot House (chart house) and the Flag Plot.

(i) Plotting boards of generous size and adapted to clear represe tation of the movements of several groups of aircraft. Provisions f

(j) Blackboard showing fighter patrols in the air, call signs, t
of departure, availability of fighters on deck, etc.

(k) Bearing indicators (circuits GT, 2PD, 2PE, 2PS, and 2PM)
found necessary after further study of the problem.

(1) One train indicator to indicate Radar antenna train. It wil
desirable to combine this with a gyro-repeater.

3. MISCELLANEOUS NOTES

(a) Since Radar detects aircraft as an instantaneous present bea
and range on a screen, and does not produce a continuous record sho
course and speed, and indications cannot be used immediately as di
tion to fighters. It is necessary at present to predict manually
future position of the enemy which the fighters may be directed
intercept; in other words it is necessary to forecast enemy movem

(b) A convenient method of keeping the Radar plot is to use a m
ing board covered with a piece of celluloid, and a "chinagraph" pen
or by a special board with tracing paper over the plotting sheets.
second method provides a record of the operation which is of valu
analyzing the operations.

(c) It is important that the fighters be relieved of the detail
navigation in carrying out the interception so that they may be fre
concentrate on looking out for the enemy planes, and be ready to en
them. To accomplish this the FDO should transmit to the pilot magn
courses to steer, and indicated speeds at which to fly. General
however, unless the FDO has very exact information of the existing c
conditions, he should inform the fighters of the enemy's altitu
rather than specify the altitude for the fighters.

(d) The Radar reports will be received as a series of bearings
ranges relative to the reporting ship, so that the FDO will be prese
with a relative rather than a geographical picture. Since both
friendly and enemy planes are reported through the same medium, the
is concerned only with their relative positions in directing
fighters to an interception. Thus, the wind and own ship's course
speed need not be applied to the courses and speeds transmitted,
corrections to the fighter's courses will result from the relat
motion of the opposing planes as indicated by the subsequent Radar
ports. A separate geographical plot may be maintained, but genera
this is slower and of less value to the FDO in directing the interc

(e) When Radar reports are not available, as in the case of low f ing shadowers, it is very desirable that both types of planes be repor through the same medium so that a relative plot may be kept. If this not possible, it will be necessary for the FDO to use any informat available, and may even require that the fighters be directed to po tions relative to the carrier or other ships, to circle, or to sea relative sectors.

F. VISUAL COMMUNICATION WITH PLANES

1. During radio silence or in the event of casualty to radio equ ment it is possible to communicate by flashing light with fighters o head. This method of communication cannot be used if the fighters above 6,000 feet, and in any case it is very slow. This system is c sidered too impractical for use except as a last resort, but train should be conducted in order to make it as effective as possibl

2. It has been suggested that the guns of the fleet be trained on bearing of the enemy planes as a visual signal, but the British h found that the fighters do not see this signal, even though the barrels are covered with white paint to give them prominence.

3. Bursts of anti-aircraft gunfire give a good indication of posit if they can be placed near the enemy planes, but do not help if they fired while the enemy is still out of range, as they fall very short the target and are apt to mislead the fighter patrol who cannot eas visualize the line of fire.

G. NOTES ON THE USE OF RADAR DIRECTED FIGHTERS FOR THE PROTECTION OF A NAVAL FORCE

1. The number of fighters to be sent on patrol depends on the to number of aircraft available to maintain patrol throughout the day, on the likelihood of attack during the period of each patrol.

2. Patrol is maintained over the force to be protected at a hei close to that at which enemy planes may be expected to fly, depending the existing cloud conditions.

3. The patrol should remain immediately above the fleet unless th is good reason to expect an attack from a particular direction, in wh case the patrol may be stationed up to 15 minutes from the fleet in t direction, but not outside the visible range. The fighters may patr up-sun of the fleet if shadowing aircraft are expected, or they may ma frequent sweeps in the direction of the sun.

sets, since a plane at low altitude is essentially the same as a tal ship as far as Radar is concerned. An FC set will consistently detect low flying patrol plane of medium size up to 18,000 yards.

Large flying boats have been used recently to shadow from astern o "up-sun," keeping below the horizon out of sight of the fleet, periodic ally closing to maintain contact and gather information of fleet move ments. These shadowers have usually been sighted by ships of the flee or by fleet aircraft flying in the vicinity. The position of the enem is passed to the fighter patrol, but it is difficult for them to inter cept because all touch with the enemy is lost as soon as he retires ou of sighting distance over the horizon. Aircraft shadowing from high u are more easily dealt with, because they are at sufficient height to b detected by Radar at greater distances. In the case of low shadowers i is not good policy to call down the high patrol to intercept them. In stead it is better to fly off fresh VF from the carrier. It is of th utmost importance that shadowers be destroyed or permanently driven off Even after it has appeared that the enemy planes have sighted th fleet and reported its location, it is urgent that these shadowin planes be prevented from disclosing further movements of the force to b protected.

5. Recent wartime practice of most aircraft attacking a fleet ha been to close the fleet upon a steady course until it is sighted an then to circle just beyond the visible range so as to attack from th direction of the sun. This maneuver, if carried out at high speed, als has the effect of circling round the defending fighters and so evadin them. With the use of Radar it should be possible to direct the fighte patrol to thwart this maneuver. At all times, great care must be take to keep the fighters interposed between the attack and the fleet

6. If the enemy has approached so close to the fleet that he canno make a large detour to avoid the fighters without disorganizing hi attack, the fighters may be given a position at which to intercept hin it is desirable that the interception should occur when the enemy i between 20 and 25 miles from the fleet.

7. When a unit of the Combat Air Patrol makes a visual contact wit an ememy unit the Fighter Directing Ship should cease directing tha unit in order that the officer in command of the Combat Air Patrol uni may have complete freedom to maneuver his unit. Upon completion of a attack, the FDO should be prepared to give immediate instructions as t the course to steer to return to the carrier, if it is requested, or i it is apparent that the patrol is not returning expeditiously.

8. In the absence of Radar identification or recognition equipm it is desirable to confine own air activity to a minimum to avoid confusion which results from a multiplicity of unidentified Radar c tacts. It is possible that aerial pickets and Intermediate Air Pat do more harm than good and may have to be eliminated. Combat patr may be employed more efficiently if kept alerted on the deck of carrier instead of in the air, if the combination of Radar range fighter performance make interception possible at a satisfactory dis ce from the fleet; in addition movements of friendly planes (such sector searches, arrivals and departures of attack flight, etc.) sh be furnished by the Fighter Directing Officer to the Radar Cont Officer.

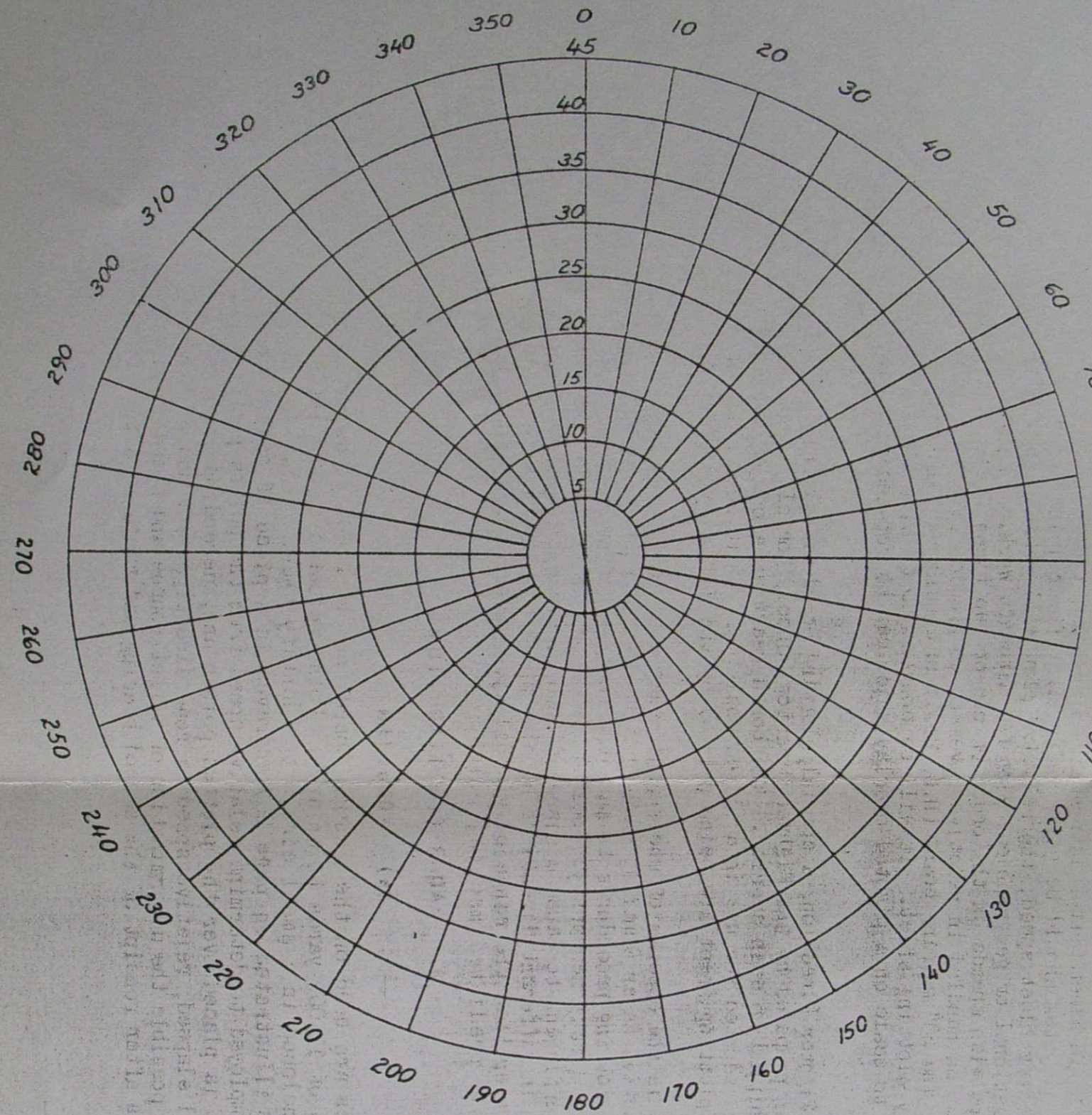
9. It will be necessary to alter the tactics of our own planes search and tracking missions. An alert enemy equipped with Radar w observe every plane which is above the horizon at any range. Searc and tracking planes should be made aware of this fact. It is poss that through judicious use of extremely low altitudes and radi changes of position when below the horizon, present day planes th selves may escape being tracked and attacked.

XII. CONCLUSION

It should be appreciated that Radar equipment is continuously und going further improvement and that the knowledge of its use is st limited. Officers and men associated with it should, therefore, b that they have some latitude in exploiting its use, and the contents this bulletin should be regarded as a guide and a basis for improve after further experience afloat.

Suggestions for changes which will lead to improvement in Ra Bulletin Number 1 will be welcomed.

PEG BOARD



Scale 1" = 2"

There is a hole at each intersection.
Pegs similar to golf tees are used.